PROGRAMMING THE MCM5003/5004 PROGRAMMABLE READ ONLY MEMORY

Prepared by
Jerry E. Prioste
Computer Applications

This note describes programming methods for the MCM5003/5004 512 bit (64x8) TTL Programmable Read Only Memory (PROM). These program methods can result in short design cycles for custom ROM circuits. Operation and circuit details of the MCM5003/5004 are given first. Then programming methods and circuitry are discussed. The simplest programmer uses only five ICs, while a more sophisticated programmer, using automatic sequencing, requires a total of 25 ICs.

MOTOROLA Semiconductor Products Inc.

PROGRAMMING THE MCM5003/5004 512 BIT (64 × 8) PROGRAMMABLE READ ONLY MEMORY (PROM)

INTRODUCTION

The MCM5003 and MCM5004 are 512 bit (64x8) TTL read only memories that can be easily programmed by the user. Other types of ROM's typically require the user to send a truth table to the manufacturer, then wait several weeks for a custom mask and processing of parts. During manufacture, the information is fixed with each new pattern requiring a different custom mask. Under this new system using the MCM5003/5004 PROM's, the user can custom program memories without experiencing a mask charge for each pattern along with associated lead time. Thus, the user can buy one device type and program it in any number of custom patterns, and do this when the devices are needed.

Some of the advantages of the MCM5003/5004 are:

1) logic levels compatible with all MDTL and MTTL families,
2) an access time of less than 75 nanoseconds,
3) field programming, and
4) a ninth bit designed into each word enabling the manufacturer to test the device properly without programming any of the normal 64x8 bit storage array.

This report deals primarily with the design of circuits that can be built by the user to program the MCM5003/5004.

FUNCTIONAL DESCRIPTION OF THE MCM5003/5004

A block diagram of the 512 bit PROM is shown in Figure 1. Six address lines (A_0 through A_5) are used to select 1 of 64 words. The memory consists of an array of 64 words by 9 bits, although the customer normally uses only 64 words by 8 bits. The 8 bit words appear on outputs B_0 through B_7. The ninth bit in the array (B_8) is used during manufacturing final test to determine if the address decoding logic is operating properly. Also, this ninth bit is used to assure that the links have fusing characteristics required by the normal 64x8 bit array. Since the ninth bit is physically farthest from the word line drivers, it is also used for worst case ac testing. The test output-pin (14) in Figure 1 provides this ninth bit.

The PROM has two chip enables (CE1 and CE2) which are "ANDED" together internally. Both chip enables must be high to enable the selection of 1 of 64 words (W_0

TABLE 1
Truth Table for MCM5003/5004

Word Number	(1)E	Inputs A5	A4	A3	A2	A1	A0	Outputs B7	B6	B5	B4	B3	B2	B1	B0
(2)X	0	X	X	X	X	X	X	1	1	1	1	1	1	1	1
0	1	0	0	0	0	0	0	(3)•	•	•	•	•	•	•	•
1	1	0	0	0	0	0	1	•	•	•	•	•	•	•	•
2	1	0	0	0	0	1	0	•	•	•	•	•	•	•	•
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
63	1	1	1	1	1	1	1	•	•	•	•	•	•	•	•

Notes: (1) E = $(C_{E1}) \bullet (C_{E2})$
(2) X = "Don't care"
(3) • is a "0" or "1", depending on program.

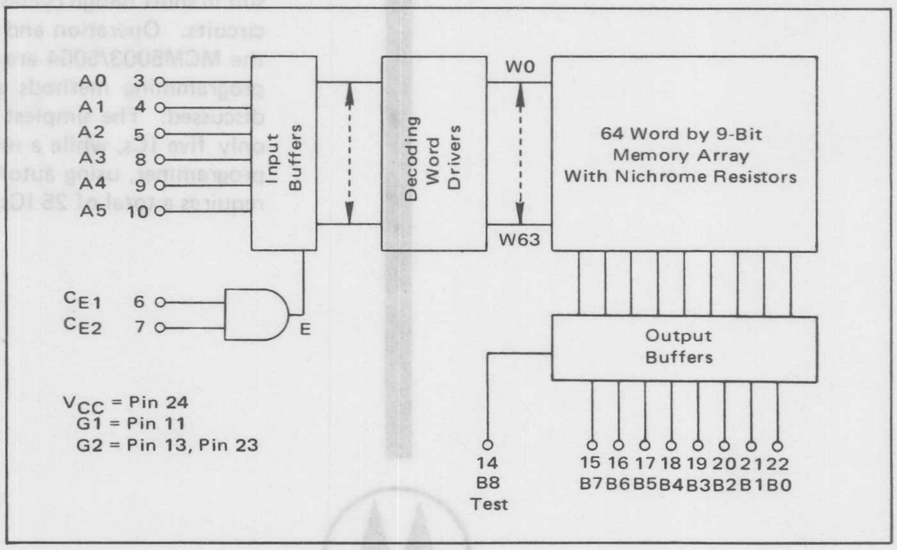

FIGURE 1 – 512-Bit PROM MCM5003/5004.

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through W_{63}) in the memory array. If one or both of the chip enables is low, then none of the word lines are selected and all the output bits would be in the high state. The MCM5003L has open collector outputs while the MCM-5004L has 2 kilohm pullup resistors on the outputs.

The truth table is shown in Table 1. Note that the word number is the decimal equivalent of the six binary inputs A_0 through A_5; with A_0 being the least significant bit (LSB), and A_5 being the most significant bit (MSB). As shown in the truth table, if the enable lines are high, then the output word (B_0 through B_7) is selected by inputs A_0 through A_5.

The device has two isolated grounds, G_1 and G_2. In normal operation G_1 and G_2 are tied together to ground, and the V_{CC} is connected to +5 volts. To program the memory array the grounds must be separated, G_1 connected to -6 volts and G_2 connected to ground. The input buffers and substrate are internally referenced to G_1; therefore, in the programming mode, the input low voltage to the address and chip-enables lines is -6.0 to -5.2 volts and the input high voltage is -4.0 to +5.0 volts. These larger voltage swings are made possible by the fact that the input Schottky diodes have a typical breakdown of 30 volts.

DESCRIPTION OF THE MEMORY ARRAY AND PROGRAMMING CIRCUITRY

The memory array and output circuitry are shown in Figure 2. The memory array consists of a thin film nichrome resistor for each memory bit, labeled R1, having a nominal value of 150 ohms. Vacuum deposition techniques are used to deposit the nichrome on a planar surface to ensure uniform thickness. Before the device is programmed, all the outputs are in a logical "0" state. Programming of the memory is accomplished by "opening" the appropriate nichrome resistor elements where a "1" state is desired.

It takes 25 to 35 milliamps of fuse current (I_f) through R1 for a duration of typically 200 milliseconds to "open" the nichrome link; however, it could take as long as one second to "open" the link in some devices.

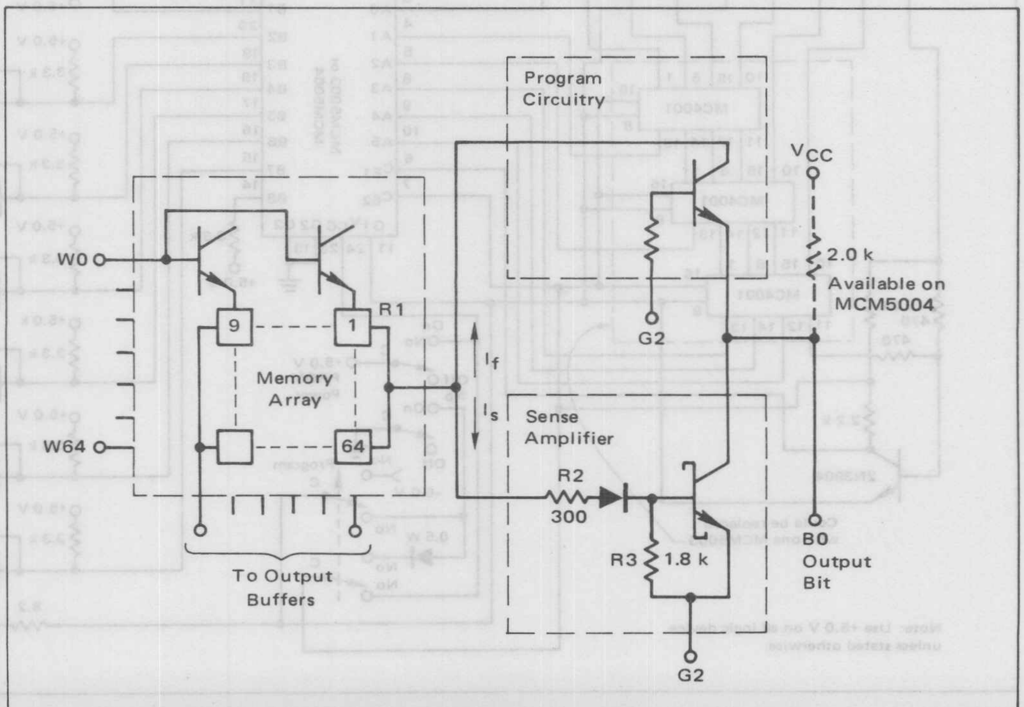
The MCM5003/5004 is unique in that it provides additional program circuitry to supply the current gain necessary to insure high reliability when fusing the memory link. To program a logic "1" into a particular memory bit, the proper bit-output line is connected to -6.0 volts (refer to Figure 1). This causes the transistor in the program circuitry (refer to Figure 2) to turn on allowing the fuse current to flow through the appropriate nichrome resistor, R1. The sense amplifier Schottky transistor turns off when programming, although about three milliamps will flow through R3 and the base-collector junction of the Schottky transistor to the bit output.

Current may also flow out of the collector of the Schottky clamped output transistor due to breakdown. This is the reason why the total fuse current leaving the output terminal is specified as a maximum of 120 milliamps. For this reason, if current limiting is used, it should accomodate 120 milliamps to insure fusing.

In normal operation when a word line is selected, the sense current flows through R1 and R2 turning the Schottky output transistor "on" causing a logic "0" at the bit output. If R1 has been fused, then current will not flow into R2 and the output transistor will be "off" causing a logic "1" to appear at the bit output. The amount of sense current, I_S, flowing through a non-fused link when selected in normal operation can be calculated as follows:

$$I_S = \frac{V_{W0} - 3\,V_{BE}}{R1 + R2} = \frac{(3.5 - 2.1)\text{ V}}{(150 + 300)\,\Omega} \approx 3.1\text{ mA}$$

FIGURE 2 — Memory Array and Output Circuitry



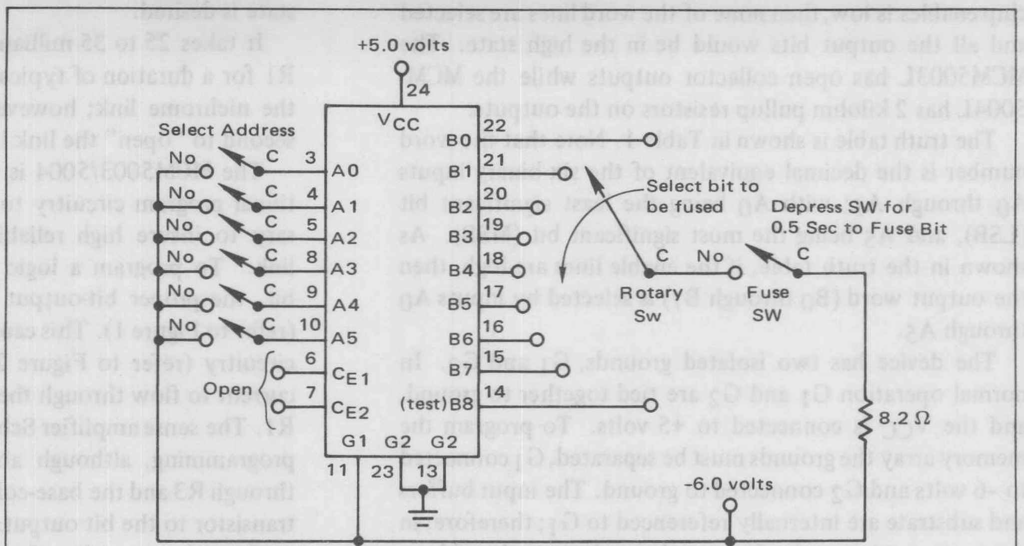


FIGURE 3 – Programming Connections for 512-Bit PROM.

where V_{W0} appears at the base of the transistor in the memory array and is nominally 3.5 volts due to address decode circuitry. Therefore the ratio of fuse current to sense current is 8 to 1 (assuming the minimum fuse current to be about 25 mA). This high ratio improves the reliability of the memory and minimizes the probability of a memory link becoming fused during normal operation.

MANUAL PROGRAMMING OF THE 512-BIT PROM

Programming the MCM5003/5004 is a simple operation requiring a small amount of equipment. Figure 3 shows the programming connections necessary to program the device. Only two power supplies, seven single-pole single throw switches, and one eight-position rotary switch are required. Note that a switched voltage at the output bit is

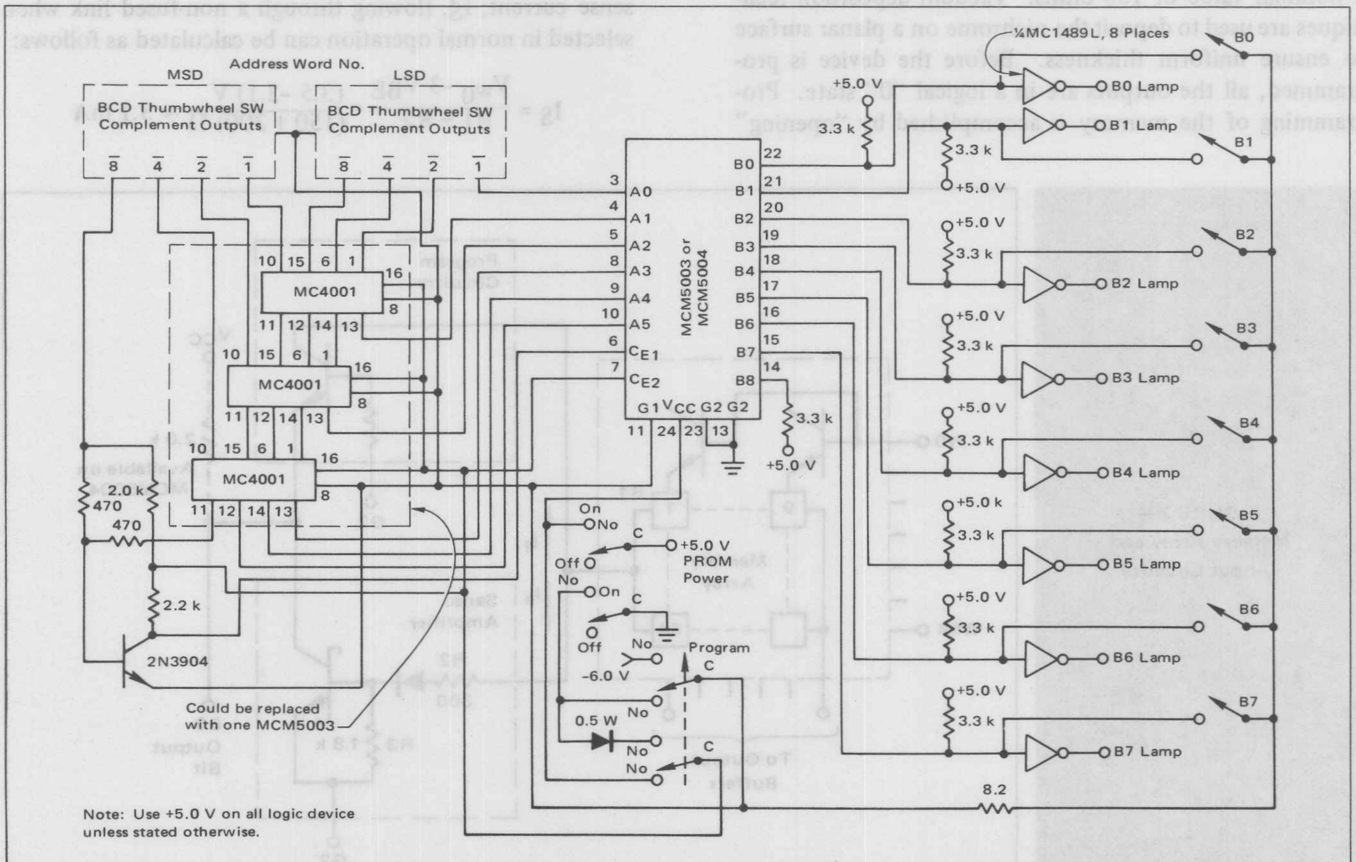


FIGURE 4 – Manual 512-Bit PROM Programmer

adequate and reliable for fusing. The small series resistance at the output bit is to limit current to 120 milliamps at -5.0 volts, which appears at point C on the rotary switch. This level is adequate for fusing.

Only one memory link is fused at a time since the power dissipation of the device would be excessive if more than one bit were fused simultaneously. The programming procedure for the connections shown in Figure 3 are:

1) Select the address code by connecting the proper address bits to -6.0 volts for a logic "0" and unconnected for a logic "1". The logic "0" can be from -6.0 to -5.2 volts while the logic "1" can be from -4.0 to +5.0 volts or an open condition.

2) Set the rotary switch to the output bit in which a logical "1" is desired.

3) Press the fuse switch for approximately a second. This connects -6.0 volts to the output and causes fuse current to flow.

4) Repeat steps 2 and 3 until all the output bits for that word in which logical "1's" are desired have been fused.

5) Select the next address code and repeat steps 2, 3, and 4.

Although the connections in Figure 3 are straightforward and simple to implement for programming, some disadvantages are obvious. The programming of the total unit is cumbersome and insuring that the device has been programmed properly could be difficult. For instance, setting the six address switches to the proper binary code for address selection can be cumbersome. This could be overcome to some extent by using two thumbwheel switches with octal coding instead of 6 binary switches. Also, a display is needed to verify that the bit has indeed been fused.

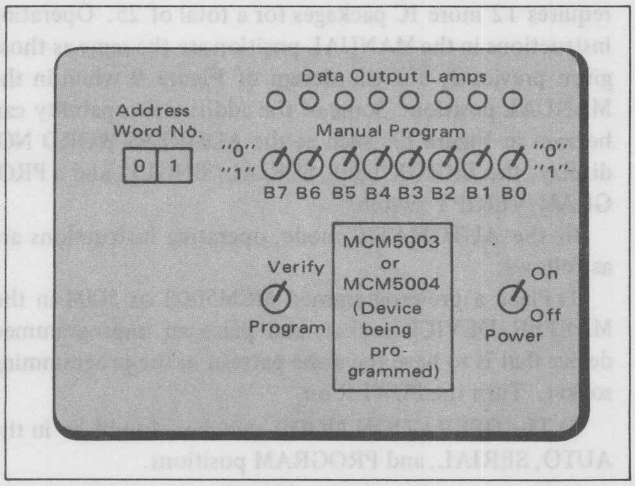
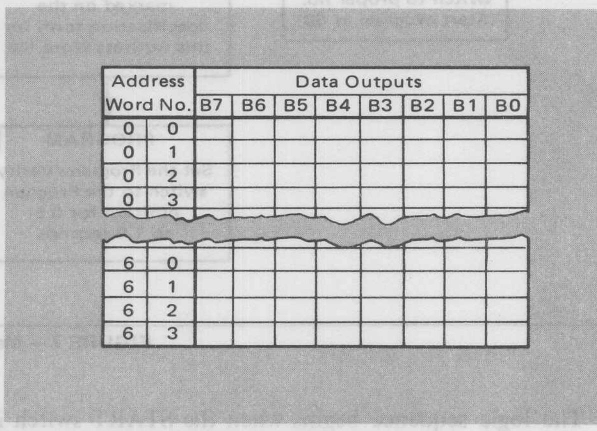


FIGURE 5 – Front Panel Layout for Manual Programmer

It should be noted that the G1 terminal must be at ground (not -6.0 volts) when the outputs are checked for determining if the output bits have been fused properly.

Figure 4 shows the schematic of a simple manual programmer that overcomes some of these objections. The MC1489 quad line receivers are used to show the contents of the output bits by driving 5.0 volts, 20 mA bulbs.

Figure 5 shows the panel layout of the manual programmer of Figure 4. The address word number is selected using two BCD thumbwheel switches. Three MC4001's TTL standard read only memories are used to convert the BCD code to the code that is required at the address inputs. The transistor is used to inhibit programming of the PROM if an illegal number is selected for the address inputs (64 or greater).



Address Word No.		B7	B6	B5	B4	B3	B2	B1	B0
0	0								
0	1								
0	2								
0	3								
6	0								
6	1								
6	2								
6	3								

FIGURE 6 – PROM Specification Form

Figure 6 shows a typical specification form which could be used for specifying the custom program. Place an X in each bit position that is to be a logic "1". This form can be used to set-up the switches when programming the PROM.

The manual program instructions are given in Figure 7.

The PROGRAM/VERIFY switch must simultaneously be set along with the proper output switch for each fused bit. Remember, that if one bit is fused in error, the device cannot be used for that particular program.

MANUAL/AUTOMATIC PROGRAMMING OF THE PROM

An improved design for a manual/automatic programmer is shown in the block diagram of Figure 8. This design has additional features requiring 8 extra ICs that optimize cost/performance with a total of 13 IC packages. The panel layout is shown in Figure 9.

In this design, the fusing switch should be pressed once for programming all 8 bits in the word automatically. If more than one device is to be programmed with the same pattern, additional devices can be programmed automatically one word at a time without having to set up the MANUAL PROGRAM SWITCHES. Also, a CONFIRM lamp lights when the DATA OUTPUTS of the MCM5003 or MCM5004 being programmed agree with the master device outputs in the AUTO position, or the MANUAL PROGRAM SWITCHES in the MANUAL position. A pulse width control potentiometer (PW CONTROL) is used to increase fusing pulse width if required. Extra capability is provided with a CLEAR switch for stopping the programming at any time.

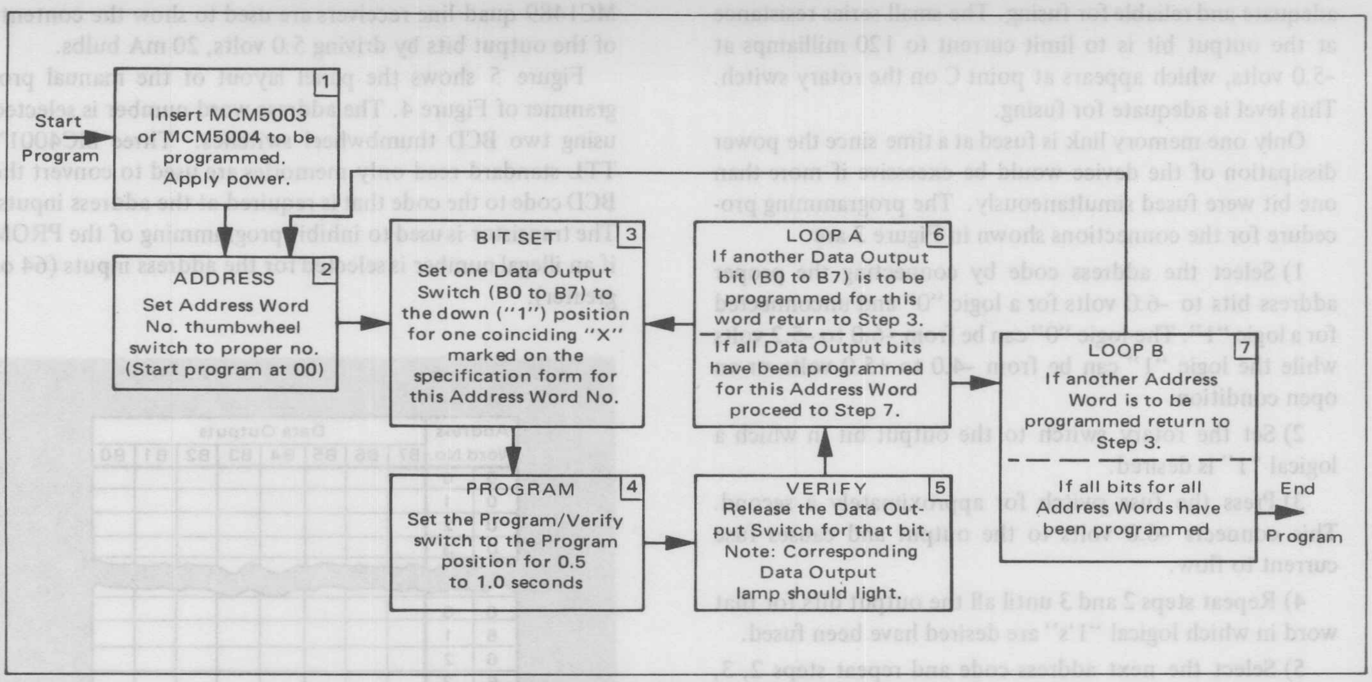


FIGURE 7 – Manual Programming Instructions

The logic sequence begins when the START switch is pressed. Fusing begins when the switch is released. The wiring schematic for the MANUAL/AUTOMATIC programmer is given in Figure 10. The MC839 bit number counter (See Figure 8 or Figure 10.) directs the MC7445 decoder driver as to which bit to fuse. At the end of each fuse pulse (on the trailing edge) the MC839 counter is advanced one count. After a short delay, the fuse pulse occurs again. See Figure 11 for the Timing Diagram sequence.

The Z output of the MC8312 8 bit data selector determines which bit is to be fused. Fusing occurs if Z is in a "1" condition. The D input of the MC7445 provides an enable input. When the D input is high, only Q8 or Q9 of the MC7445 can be enabled and they are unconnected. Only 2 – MC1812 quad 2-input exclusive OR gates are required to compare and confirm the two words.

In Figure 10, the G_1 terminal of the MCM5003 or MCM5004 is fixed at ground. The V_{CC} terminal is switched to +11 volts, and the G_2 terminal is switched to +6.0 volts during programming. This eliminates the use of translators at the address inputs to switch G_1 to –6.0 volts during programming.

Operating instructions for the panel in Figure 9 with PROGRAMMING MODE switch in the MANUAL position are given in the flow diagram of Figure 12.

After one device has been programmed, other devices may be programmed with the same pattern by placing the programmed device in the MASTER DEVICE socket and placing the PROGRAMMING MODE switch in the AUTO position. Programming instructions are the same as given in Figure 12 except that step 3 is omitted.

The MANUAL/AUTO rotary switch could be eliminated by "hardwire OR-ing" the proper center position of the manual load switches to the corresponding bit output of the master device. However, this does add an additional step when the master device is used during automatic programming mode. The manual program switches must then be in the logic "1" position.

In considering cost/performance, the design of Figure 10 would seem adequate. However, the START FUSING switch must be pressed 64 times for each fully programmed device.

AUTOMATIC SEQUENCING THE PROM

Panel layout of a more sophisticated design is shown in Figure 13. The schematic of Figure 14 illustrates automatic control capability. The resulting additional capability requires 12 more IC packages for a total of 25. Operating instructions in the MANUAL position are the same as those given previously for the design of Figure 9 when in the MANUAL position. Some of the additional capability can be seen in Figure 13, such as the ADDRESS WORD NO. display, the ERROR light, SERIAL/SINGLE, and a PROGRAM/VERIFY switch.

In the AUTOMATIC mode, operating instructions are as follows:

1) Place a pre-programmed MCM5003 or 5004 in the MASTER DEVICE socket, and place an unprogrammed device that is to have the same pattern in the programming socket. Turn the POWER on.

2) The OPERATION MODE switches should be in the AUTO, SERIAL, and PROGRAM positions.

3) Momentarily press the CLEAR switch. The address word number display should read-out "00".

4) Momentarily press the START switch. The IN PROCESS lamp should light, and the ADDRESS WORD NO. display should sequence one count every few seconds. In approximately two minutes, the IN PROCESS lamp should turn off; the ERROR lamp should be off; the COMPARE lamp should be lit, and the ADDRESS WORD NO. should

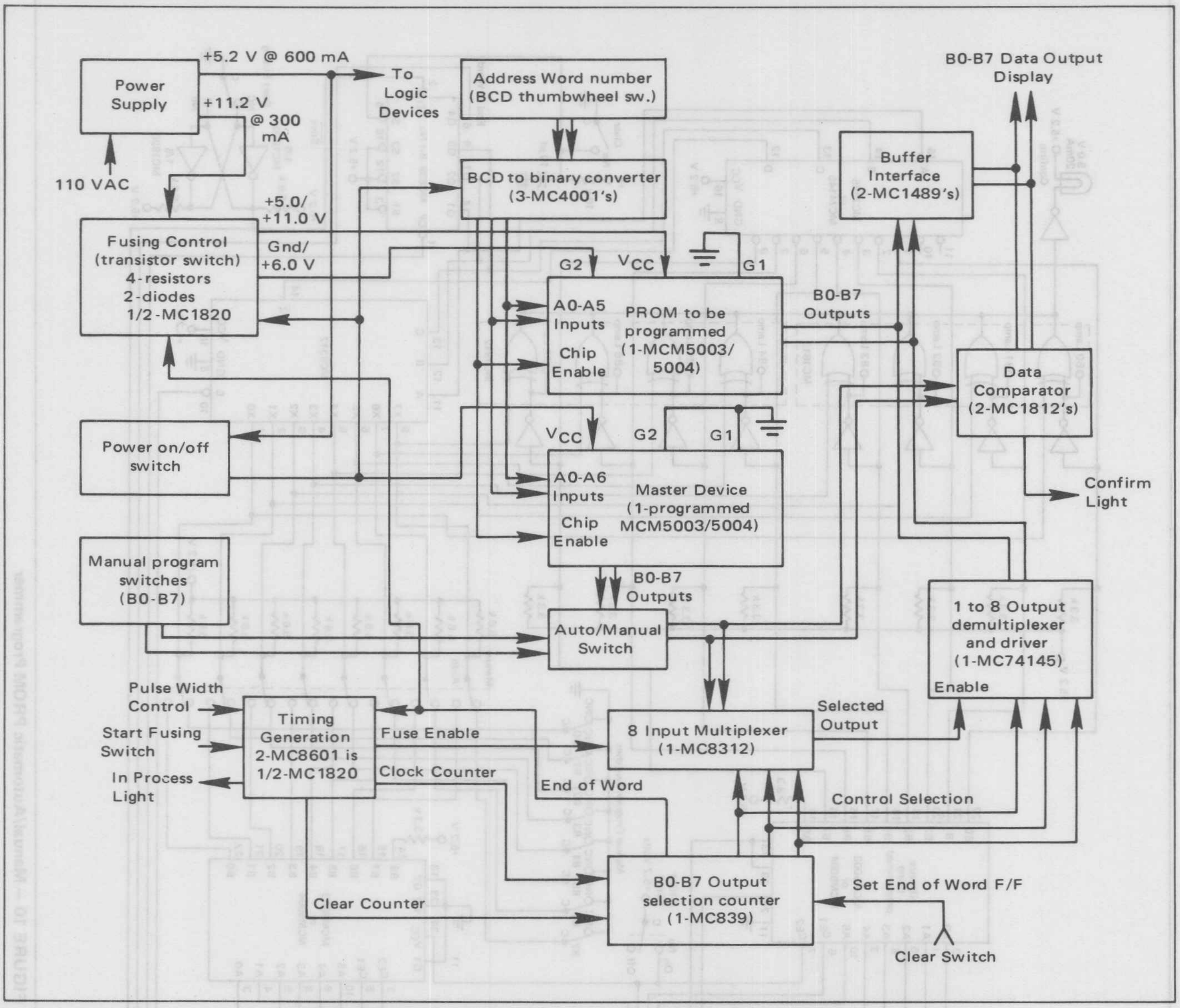
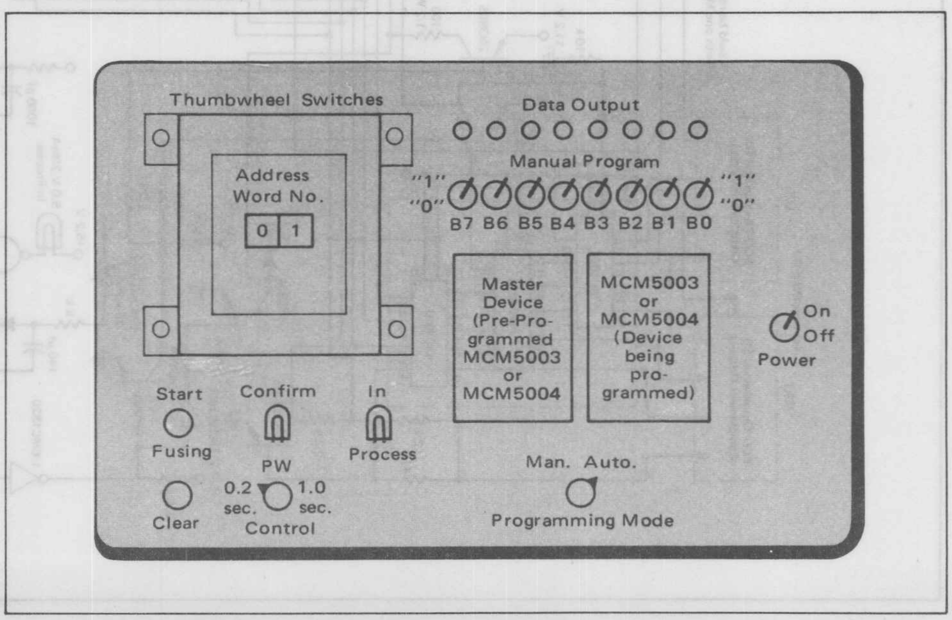


FIGURE 8 – Block Diagram of Manual/Automatic PROM Programmer

FIGURE 9 – Front Panel Layout for Manual/Automatic Programming



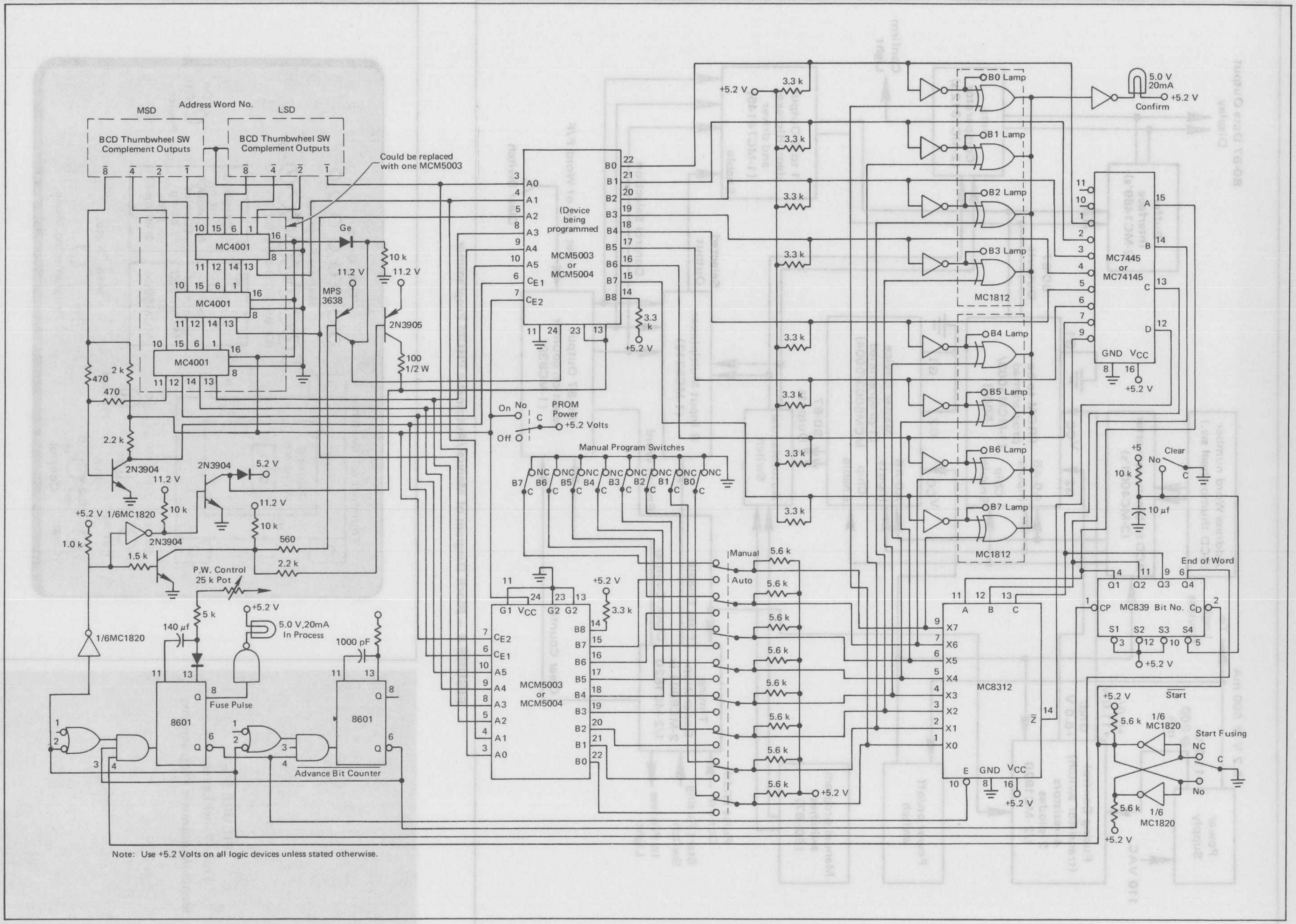


FIGURE 10 – Manual/Automatic PROM Programmer

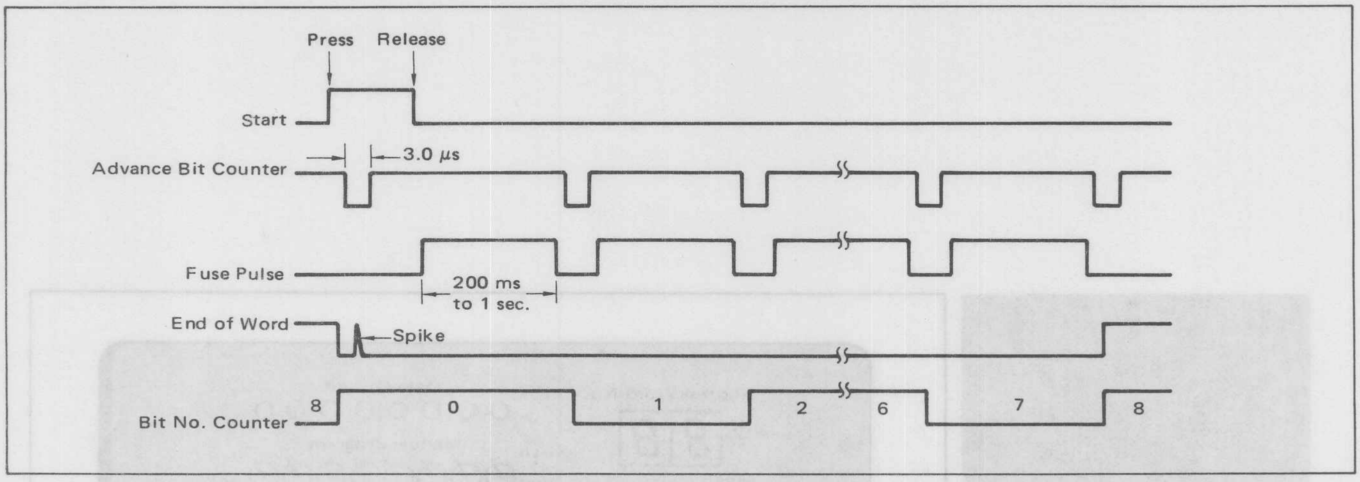


FIGURE 11 – Timing Diagram

read "63". This indicates that programming is complete, and that the PROM has been programmed correctly.

If an error should occur during programming, the ERROR lamp will light, and the IN PROCESS lamp will turn off. Also, the ADDRESS WORD NO. will indicate the address in which the error, occurred, and the DATA OUTPUTS will show which bit was in error. If this happens, the PW CONTROL (pulse width) should be turned fully clockwise for maximum fusing. Then, the START FUSING switch should be momentarily pressed. If this sequence does not work, the device to be programmed should be replaced. In normal operation, the PW CONTROL is in the counter-clockwise position in order to keep programming time at a minimum.

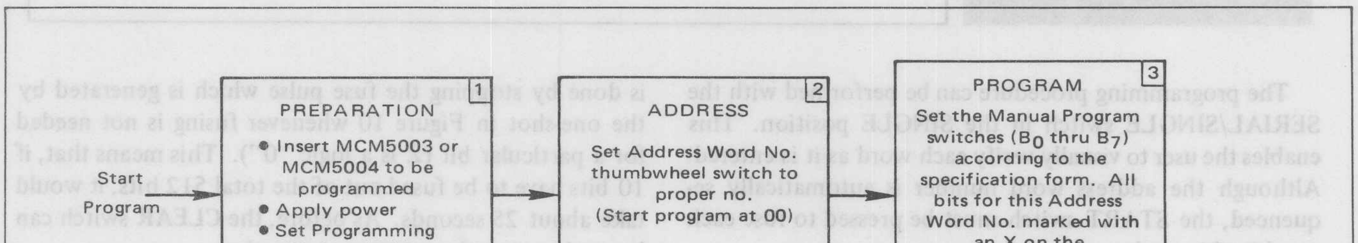


FIGURE 12 – Manual/Automatic Programming Instructions

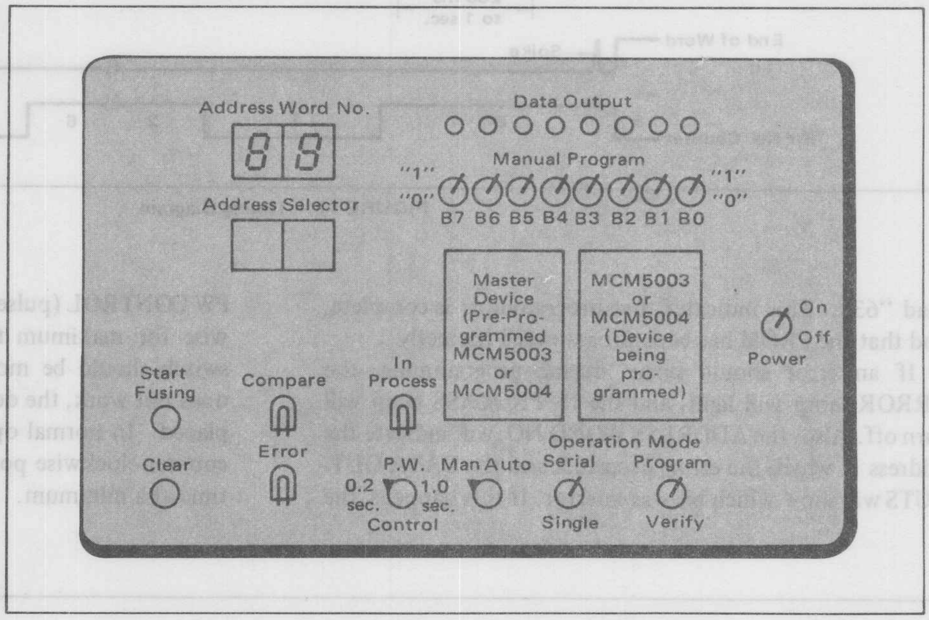


FIGURE 13 — Front Panel Layout for Automatic Sequence Programming

The programming procedure can be performed with the SERIAL/SINGLE switch in the SINGLE position. This enables the user to visually verify each word as it is entered. Although the address word number is automatically sequenced, the START switch must be pressed to fuse each word in this mode.

The MANUAL OPERATION MODE can be used to fuse words into the PROM in any order desired. That is, word 5 could be fused first, and then the next word to be fused could be word 29.

Another available mode of operation consists of the OPERATION MODE switches in the positions: AUTO, SERIAL, and VERIFY. The AUTOMATIC mode procedure is used. In this mode it takes approximately two seconds to verify that the programmed device has the same pattern as the master device.

The timing diagram for the tester is shown in Figure 15. Note that added logic decreases the operating time. This is done by stopping the fuse pulse which is generated by the one-shot in Figure 10 whenever fusing is not needed for a particular bit (Z is a logic "0"). This means that, if 10 bits have to be fused out of the total 512 bits, it would take about 25 seconds. As before, the CLEAR switch can be used to stop the program at any time.

SUMMARY

There are many possible combinations of design for programmers. Those illustrated in this note give a wide range of possibilities depending on the needed application. These procedures should provide maximum flexibility with minimum logic.

A mask option ROM, the MCM4003, is available as a pin-for-pin replacement of MCM5003/5004. This device can be used when one pattern is needed in sufficient quantity to warrant a conventional custom mask.

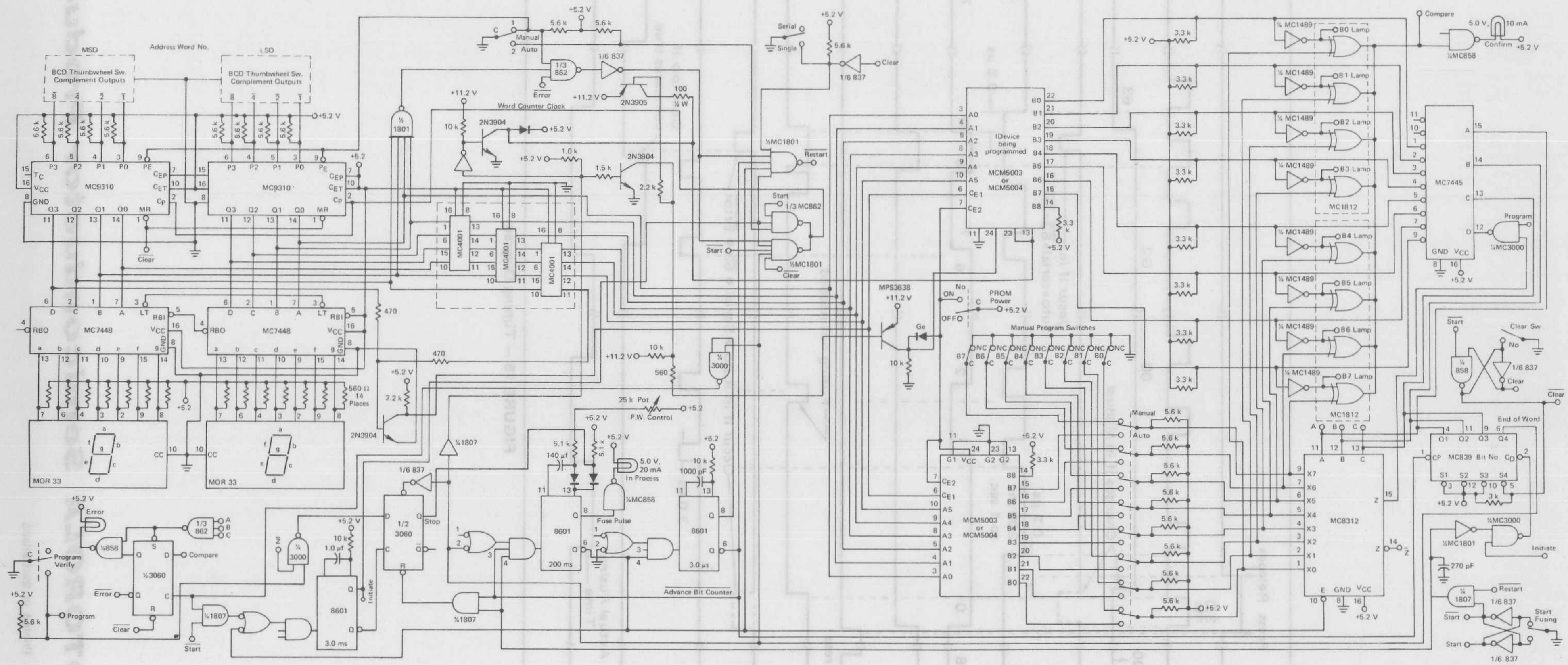


FIGURE 14 – Automatic Sequence PROM Programmer

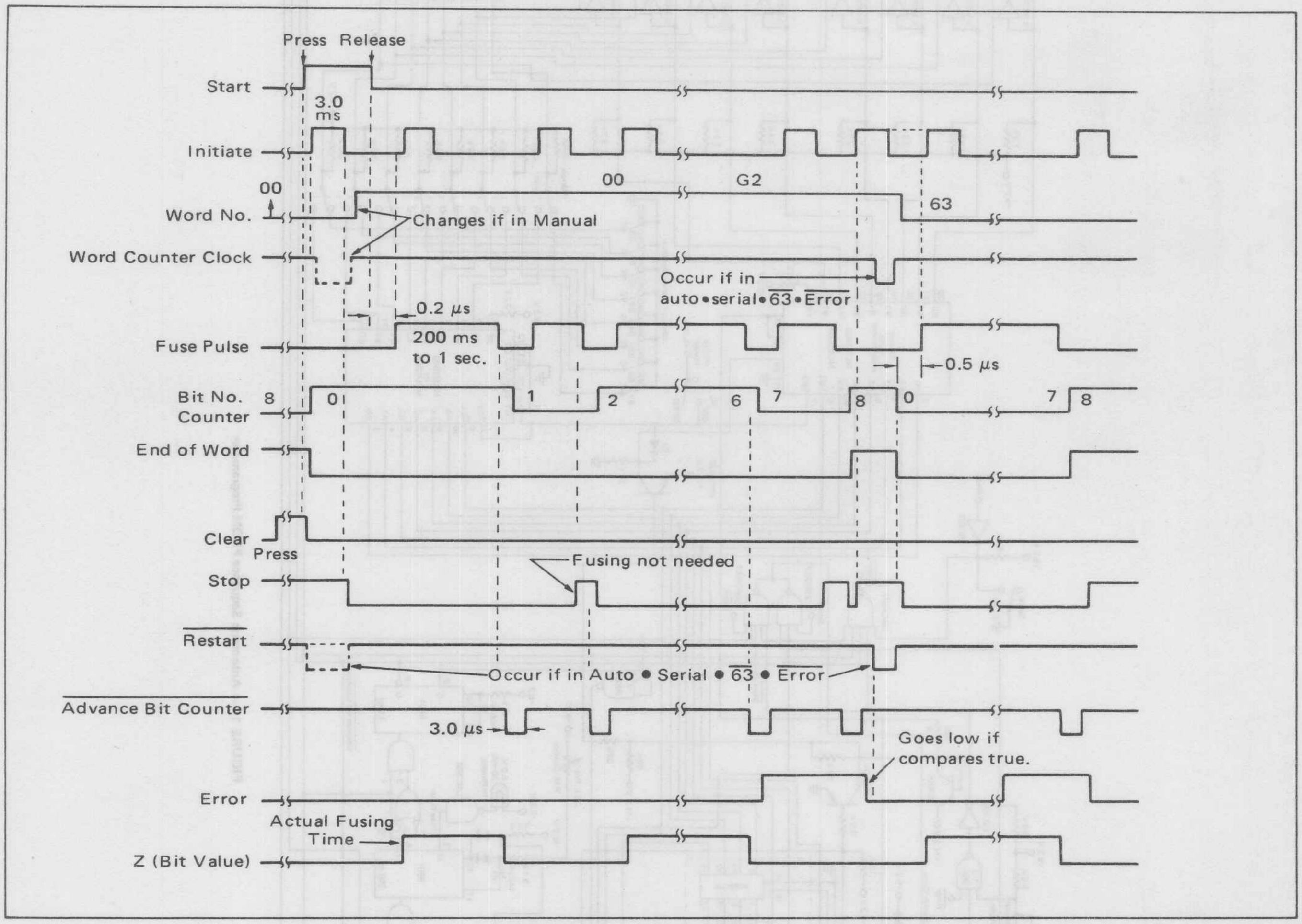


FIGURE 15 – Timing Diagram

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